Chapter 1 - General Principles

Figure 01.00

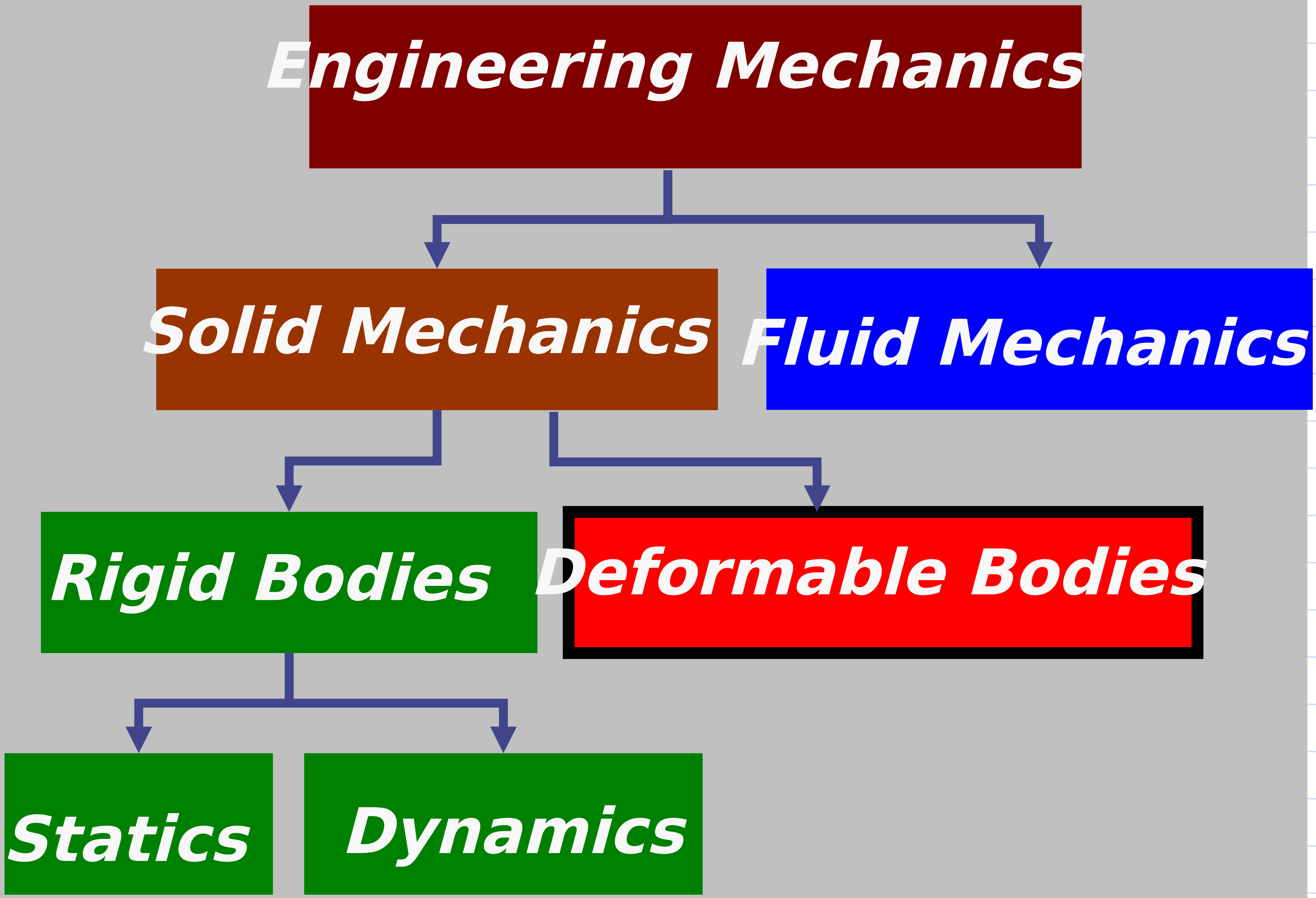
Objectives

1. **To provide an introduction to the basic quantities and idealizations of mechanics.**
2. **To give a statement of Newton's laws of Motion and Gravitation.**
3. **To review the principles for applying the SI system of units.**
4. **To examine the standard procedures for performing numerical calculations.**
5. **To present a general guide for problem solving.**

Definition

Mechanics:

Branch of physical sciences concerned with the state of rest or motion of bodies subjected to forces.



Engineering Mechanics
Solid Mechanics
Fluid Mechanics
Rigid Bodies
Deformable Bodies
Statics
Dynamics

Rigid Body Mechanics

- **Statics – Bodies at rest**
- **Dynamics – Accelerated motion of bodies**

Historical Development

Statics

- Depends on geometry and forces
- Simple machines
  - levers
  - pulleys
  - inclined plane
- Archimedes (287-212 B.C.)

Historical Development

<u>Dynamics</u>

- Accurate Measurement of time
- Galileo (1564-1642)
- Newton(1642-1727)

Basic Quantities

Length	Mass
■ meter ■ foot	■ kilogram ■ slug
Time	**Force**
■ second	■ newton ■ pound

Length

Needed to locate the position of a point in space and describe the size of a physical system.

Time

Conceived as a succession of events. Concepts of STATICS are time independent.

Mass

A property of matter by which we can compare the action of one body to another. This property manifests itself as a gravitational attraction between two bodies and provide a qualitative measure of the resistance of matter to a change in velocity.

Force

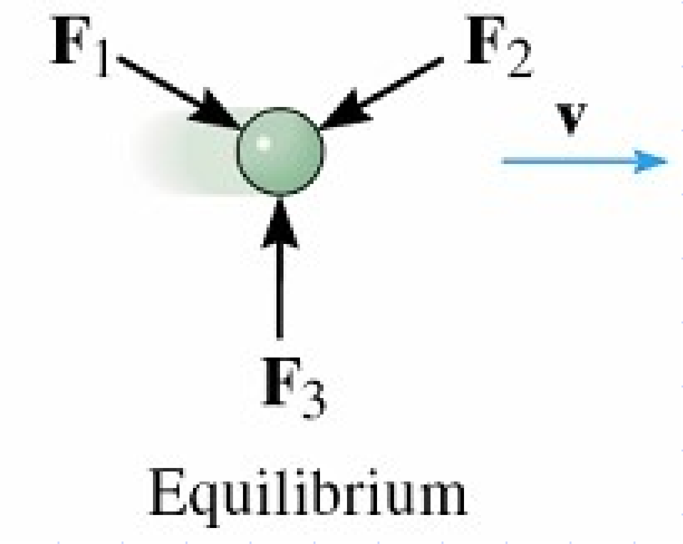
Generally considered as a push of a pull exerted by one body on another. Interaction occurs when there is direct contact between the bodies. Gravitational, electrical and magnetic forces do not require direct contact. Force is characterized by magnitude, direction and point of application.

Idealizations

1. <u>Particle</u> - an object having mass but the size is neglected.
2. <u>Rigid Body</u> - a combination of a large number of particles which remain in a fixed position relative to each other, both before and after the application of a force.

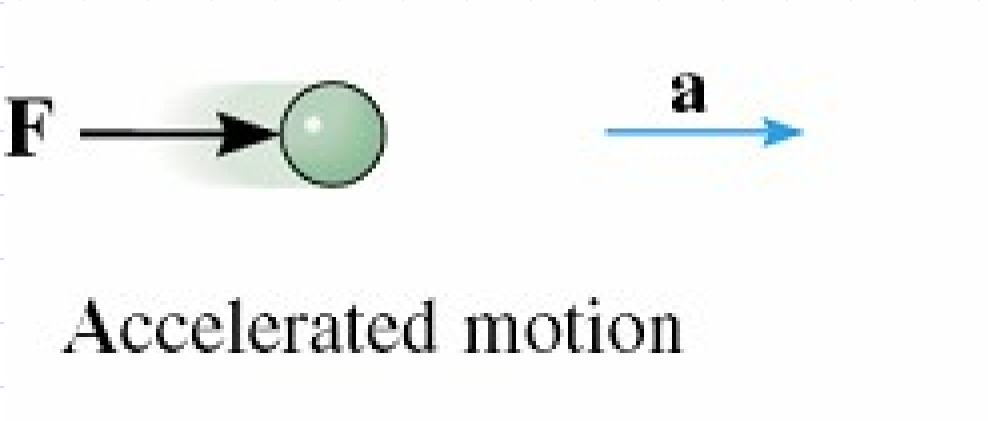
Newton's Three Laws of Motion

First Law: A particle originally at rest, or moving in a straight line with constant velocity, will remain in this state provided the particle is ***not*** subjected to unbalanced forces.



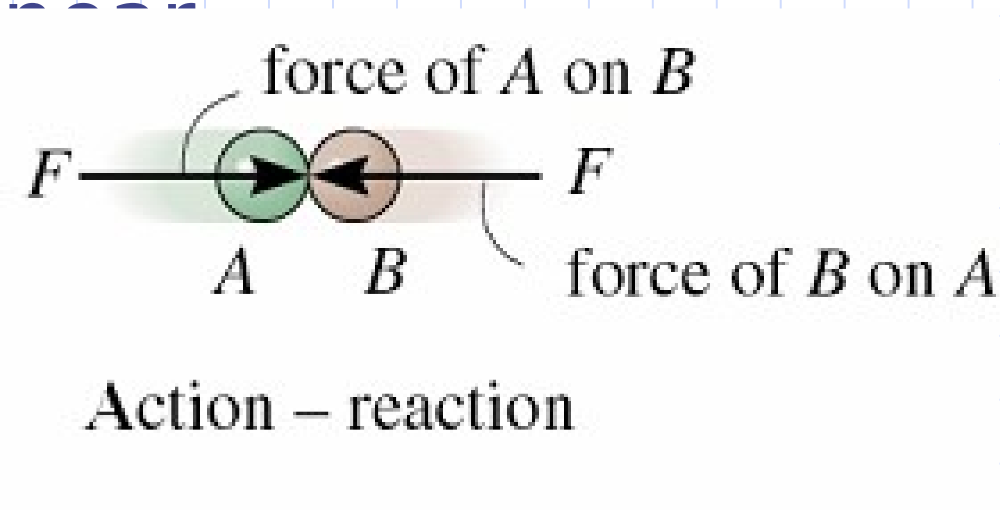
Newton's Three Laws of Motion

Second Law: A particle acted upon by an unbalanced force **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force. If **F** is applied to a particle of mass *m* then: **F** = *m***a**.



Newton's Three Laws of Motion

<u>Third Law:</u> The mutual forces of action and reaction between two particles are equal, opposite and colli



Newton's Laws of Gravitational Attraction

$$F = G\frac{m_1 m_2}{r^2}$$

Where:

F = force of gravitation

G = universal constant of gravitation

m_1,m_2= mass of two particles

r = distance between two particles

Weight

$$W = G\frac{m_1 m_2}{r^2}$$

$$\Downarrow$$

$$W = G\frac{m m_2}{r^2}$$

$$\Downarrow$$

$$W = mG\frac{m_2}{r^2}$$

m = mass of object

m_2 = mass of earth

r = distance from center of earth to particle

Units

1. Basic quantities (force, mass, length, time) are related by Newton’s second law.
2. Units used to measure quantities are not all independent.
3. Three of four units, called ***base*** units, are arbitrarily defined and the fourth is derived.

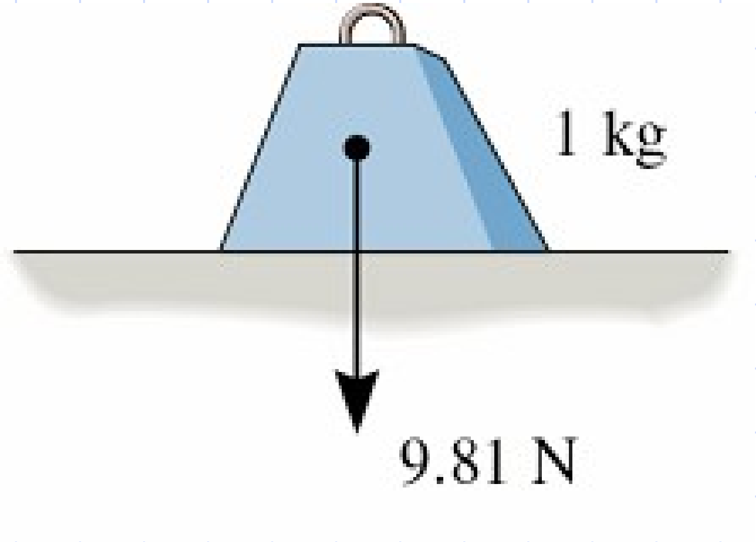
SI Units

1. Modern version of metric system.
2. Base units are length, time and mass, meter (m), second (s), and kilogram (kg)
3. Accelera

$$g = 9.81\ \frac{m}{s^2}$$

SI Units

4. Force is derived quantity measured in unit called a **newton**



$$\mathbf{1\,N = 1\,\frac{kg \cdot m}{s^2}}$$

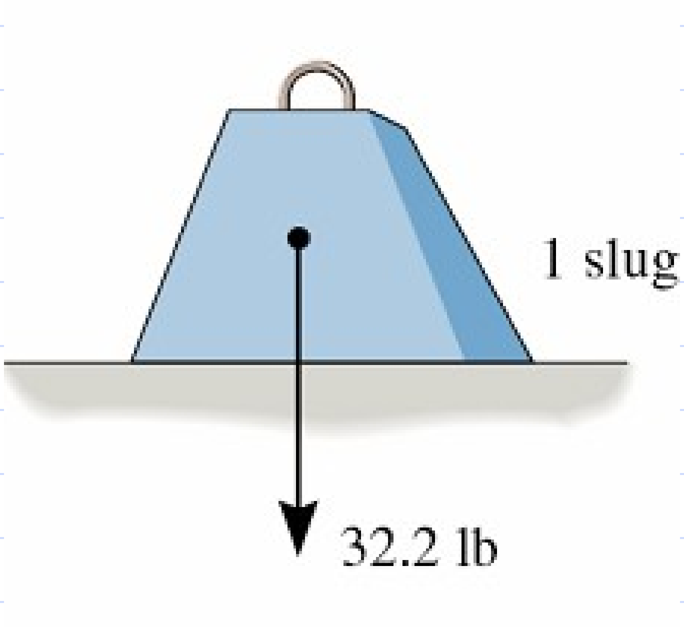
U.S. Customary Units (fps)

1. Base units are length, time and force.
2. feet (ft), second (s), and pound (lb)
3. Accele

$$\mathbf{g = 32.2\ ft/s^2}$$

U.S. Customary Units (fps)

4. Mass is derived quantity measured in a unit called a **slug:**



$$\boxed{1\,\text{slug} = 1\,\frac{\text{lb}\cdot\text{s}^2}{\text{ft}}}$$

Systems of Units

Name	Length	Time	Mass	Force
SI	**meter (m)**	**second (s)**	**kilogram (kg)**	**newton (N)**
US Customary	**foot (ft)**	**second (s)**	**slug (lb s^2/ft**	**pound (lb**

Unit Conversions

$$\text{Force: } 1\,\text{lb} = 4.4482\,\text{N}$$

$$\text{Mass: } 1\,\text{slug} = 14.5938\,\text{kg}$$

$$\text{Length: } 1\,\text{ft} = 0.3048\,\text{m}$$

Prefixes for SI units

	Exponential form	Prefix	SI symbol
Multiple			
1,000,000,000	10^9	giga	G
1,000,000	10^6	mega	M
1,000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000001	10^{-6}	micro	μ
0.000000001	10^{-9}	nano	n

Concepts to Study

1. Dimensional Homogeneity
2. Significant Figures
3. Rounding Off Numbers
4. Calculations

Dimensional Homogeneity

Each of the terms of an equation must be expressed in the same units.

$s = v\,t + 1/2\;a\,t^2$

s is position in meters

v is velocity in m/s

a is acceleration in m/s^2

t is time in seconds

$m = m/s \bullet s + m/s^2 \bullet s^2 = m$

Significant Figures

1. Accuracy specified by number of significant figures.
2. Defined as any digit including a zero (provided it is not used to specify the location of a decimal point).
3. 5604 and 34.52 both have four significant figures

Engineering Notation

1. Does 40 have one or two significant figures?
2. Engineering notation uses powers of ten with exponents in multiples of three.
3. 40 written as 0.04 (10^3) is forty to one significant figure and 0.040 (10^3) is forty to two significant figures.

Calculations

- When performing calculations retain a greater number of digits than the problem data.
- Engineers usually round off **final answer** to three significant figures. Intermediate calculations are usually done to four significant figures.
- Answer can never have more significant figures than given data!

$$2\,{}^{\text{km}}\!/\!_{\text{h}} = 2\,\frac{\text{km}}{\text{h}}\left(\frac{1000\,\text{m}}{\text{km}}\right)\left(\frac{1\,\text{h}}{3600\,\text{s}}\right)$$

$$2\,{}^{\text{km}}\!/\!_{\text{h}} = \frac{2000}{3600}\,\frac{\text{m}}{\text{s}} = 0.555\bar{5} = 0.556\,{}^{\text{m}}\!/\!_{\text{s}}$$

$$0.556\ \frac{\text{m}}{\text{s}} = 0.556\ \frac{\text{m}}{\text{s}}\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right) = 1.824\frac{\text{ft}}{\text{s}} = 1.82\frac{\text{ft}}{\text{s}}$$

Procedure for Analysis

1. Read the problem carefully and correlate the actual physical situation with the theory studied.
2. Draw necessary diagrams and tables.
3. Apply relevant principles, generally in mathematical form.

Procedure for Analysis

4. Solve the equations algebraically (without numbers) as far as possible, then obtain a numerical answer.
5. Be sure to use a consistent set of units.
6. Report the answer with no more significant figures than the accuracy of the given data.
7. Decide if answer seems reasonable.
8. Think about what the problem taught you!

Important Points

1. Statics is the study of bodies at rest or moving with constant velocity.
2. A particle has mass but a size that can be neglected.
3. A rigid body does not deform under load.
4. Concentrated forces are assumed to act at a point on a body.

Important Points

1. Newton’s three laws of motion must be memorized!
2. Mass is a property of matter that does not change from one location to another.
3. Weight is the gravitational attraction of the earth on a body or quantity of mass. Its magnitude depends on the location of the mass.

Important Points

1. In the SI system the unit of force is the newton. It is a derived quantity. Mass, length and time are the base quantities.
2. In the SI system prefixes are used to denote large or small numerical quantities of a unit.
3. Perform numerical calculation to several significant figures and report answers to three significant figures.
4. Be sure that all equations are dimensionally homogeneous.

Objectives - Review

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5. To present a general guide for problem solving.